Transformer / line loss calculations

This document gives a brief overview of transformer loss and line loss calculations and describes how these calculations are implemented in the PowerLogic™ ION9000, ION8800, ION8650, ION8600, ION7550/7650, and ION7400 meters.

NOTE: The information contained here shows theoretical examples of how the calculations should work, and is only intended to provide guidance in calculating transformer and line losses specific to the meter's actual electrical connection method and physical installation location.

What's in this document

Schneider Electric

Safety information

Important information

Read these instructions carefully and look at the equipment to become familiar with the device before trying to install, operate, service, or maintain it. The following special messages may appear throughout this manual or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of either symbol to a "Danger" or "Warning" safety label indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

> ## ⚠ DANGER
>
> **DANGER** indicates a hazardous situation which, if not avoided, **will result in** death or serious injury.

> ## ⚠ WARNING
>
> **WARNING** indicates a hazardous situation which, if not avoided, **could result in** death or serious injury.

> ## ⚠ CAUTION
>
> **CAUTION** indicates a hazardous situation which, if not avoided, **could result in** minor or moderate injury.

> ## *NOTICE*
>
> **NOTICE** is used to address practices not related to physical injury.

Please note

Electrical equipment should be installed, operated, serviced and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material. A qualified person is one who has skills and knowledge related to the construction, installation, and operation of electrical equipment and has received safety training to recognize and avoid the hazards involved.

Overview

Loss compensation is used when a meter's actual location is different from the electrical location where change of ownership occurs; for example, where meters are connected on the low-voltage side of power transformers when the ownership change occurs on the high-side of the transformer. This physical separation between meter and actual billing point results in measurable losses. Compensating for this loss — Loss compensation — is the means of correcting this meter reading. Losses may be added to or subtracted from the meter registration.

Meters are usually installed on the low-voltage side of a transformer because it is more cost-effective. There are also cases where change of ownership may occur halfway along a transmission line where it is impractical to install a meter. In this case, power metering must again be compensated.

⚠ CAUTION

HAZARD OF UNINTENDED OPERATION AND INACCURATE TEST RESULTS

- The device must only be configured and set by qualified personnel with a thorough understanding of ION architecture and the system in which the meters and software are installed.
- Due to the variation in installations, advanced knowledge of power systems and connection methods is required before transformer loss compensation can be properly implemented.
- Data parameters should only be programmed by qualified personnel that have appropriate training and experience with Transformer Loss Compensation calculations.

Failure to follow these instructions can result in incorrect test reports and/or data results.

Line loss and transformer loss after the PCC

The PCC (Point of Common Coupling) is the interchange point between the distribution grid and a particular customer. Unlike losses that occur within a transmission/distribution network, which cannot be allocated to a single customer and must be rolled into the per-unit cost of electricity, losses that occur after the PCC can be measured and allocated accordingly.

Causes of line loss

Line losses are a result of passing current through an imperfect conductor such as copper. The conducting material has characteristic impedance that produce a voltage drop along the line proportional to the current flow. The total line impedance can be determined from these elements:

Element	Definition
$\frac{r}{l}$	Per unit length resistance
$\frac{x}{l}$	Per unit length reactance

Element	Definition
L	Total length in units
R	Resistive component
Z	Impedance
P_{loss}	Active power loss
X	Reactive component
Q_{loss}	Reactive power loss

The resistive component (R) of the impedance (Z) contributes to active power losses (Ploss), while the reactive component (X) contributes to reactive power losses (Qloss).

The line-losses can be calculated based on the measured current load as:

$$LLW = P_{loss} = I \times \left(I \times \frac{r}{l} \times L \right) = I^2 \times R \qquad (1)$$

$$LLV = Q_{loss} = I \times \left(I \times \frac{x}{l} \times L \right) = I^2 \times X \qquad (2)$$

For a 3-phase system, the losses for each phase are calculated separately according to the measured current as:

$$P_{loss-tot} = (P_{loss-a} + P_{loss-b} + P_{loss-c}) = (I_a^2 \times R_a + I_b^2 \times R_b + I_c^2 \times R_c) \qquad (3)$$

$$Q_{loss-tot} = (Q_{loss-a} + Q_{loss-b} + Q_{loss-c}) = (I_a^2 \times X_a + I_b^2 \times X_b + I_c^2 \times X_c) \qquad (4)$$

If we assume that the per-phase impedance is similar and use the average impedance, the equation simplifies to:

$$LLW = P_{loss-avg} = \frac{(I_a^2 + I_b^2 + I_c^2)}{3} \times R = I_{avg}^2 \times R \qquad (5)$$

$$LLV = Q_{loss-avg} = \frac{(I_a^2 + I_b^2 + I_c^2)}{3} \times X = I_{avg}^2 \times X \qquad (6)$$

Causes of transformer loss

Power transformer losses are a combination of the power dissipated by the core's magnetizing inductance (iron loss) and the winding's impedance (copper loss). Iron losses are a function of the applied voltage and are often referred to as "no-load losses" - they are induced even when there is no load current. Copper losses are a function of the winding current and are often referred to as "load losses". These losses are calculated for any operating condition if a few parameters of the power transformer are known. The transformer manufacturer commonly provides this information on the transformer test sheet:

- rated total kVA of the power transformer (VA_{TXtest}).

- rated voltage of the power transformer (V_{TXtest}).

- No-load test watts ($LWFe_{TXtest}$) - the active power consumed by the transformer's core at the rated voltage with no load current (open circuit test).

- Full-load test watts ($LWCu_{TXtest}$) - the active power consumed by the transformer's windings at full load current for rated kVA (short circuit test).

- %Excitation current - ratio of No-load test current (at rated voltage) to full load current.

- %Impedance - ratio of Full-load test voltage (at rated current) to rated voltage.

The No-Load and Full-Load VAR losses ($LVFe_{TXtest}$ and $LVCu_{TXtest}$) may not be provided, but are calculated from the above data.

$$LVFe_{TXtest} = \sqrt{\left(VA_{TXtest} \times \frac{\%Excitation}{100}\right)^2 - (LWFe_{TXtest})^2} \qquad (7)$$

$$LVCu_{TXtest} = \sqrt{\left(VA_{TXtest} \times \frac{\%Impedance}{100}\right)^2 - (LWCu_{TXtest})^2} \qquad (8)$$

To determine the actual transformer losses, the test losses must be scaled for use at the actual operating voltage and current.

$$LWFe = LWFe_{TXtest} \times \left(\frac{V_{actual}}{V_{TXtest}}\right)^2 \quad (9) \qquad LVFe = LVFe_{TXtest} \times \left(\frac{V_{actual}}{V_{TXtest}}\right)^4 \quad (11)$$

$$LWCu = LWCu_{TXtest} \times \left(\frac{I_{actual}}{I_{TXtest}}\right)^2 \quad (10) \qquad LVCu = LVCu_{TXtest} \times \left(\frac{I_{actual}}{I_{TXtest}}\right)^2 \quad (12)$$

Loss compensation in ION meters

ION meters that support loss compensation in their default framework are the ION8800, ION8650, ION8600, ION7650 and ION7550 meters.

The meters have the following transformer and line loss compensation features:

- Compensation performed on 1-second total power (kW total, kVAR total, and kVA total).

- Unbalanced loads are handled accurately (except in the case of line-loss of neutral conductor in a 4-Wye system).

- Losses may be added or subtracted.

- Compensation works in all four power quadrants.

- Compensation is available in Test Mode. Support for compensation on singlephase test sets is also available in Test Mode.

- Compensation works correctly when all revenue parameters are reported in secondary units (meter units).

By default the ION8800, ION8650, ION8600, ION7650 and ION7550 meters come configured to provide the following compensated registers:

- For Total kW, Total kVAR, and Total kVA quantities:
  - Real-time power
  - Demand: Thermal and Block
  - Calibration Pulsers
  - Min/Max

- For Total kWh, Total kVARh, and Total kVAh quantities
  - Energy
  - Interval Energy
  - Energy in Test Mode
  - Energy for each TOU rate

The meters offer two possible loss calculation methods. One must be selected when loss compensation is enabled:

- Method 1 (Test Sheet Method)
- Method 2 (%Loss Constants Method)

Both methods are based on the same calculations and produce identical results if the correct input parameters are programmed into the meter. The difference between these methods is in the type of parameters required to perform the loss calculations.

> **NOTE**: To simplify verification in Method 2, the user is required to calculate the parameters in advance.

Supported TLC (transformer loss compensation) configurations

Power transformer wiring (metered side)	ION8650, ION8600 Volts Mode	ION8800, ION7550, ION7650 Volts Mode
3-Wire Closed Delta	35S - 3 Wire	Delta
4-Wire WYE (3 element)	9S - 4 Wire Wye/Delta	4-Wire WYE
4-Wire WYE (2½ element)*	29S - 4 Wire Wye or 36S - 4 Wire Wye	3-Wire WYE
3-Wire WYE	9S29S - 4 Wire Wye or 36S - 4 Wire Wye	3-Wire WYE

* V2 values are only accurate for balanced loads.

Contact Schneider Electric for all other configurations.

> **NOTE**: Due to the variation in installations, advanced knowledge of power systems and connection methods is required before transformer loss compensation can be properly implemented. Data parameters should only be programmed by qualified personnel that have appropriate training and experience with transformer loss compensation calculations.

When compensation is enabled, the meter calculates transformer and line loss based on a set of input parameters. These parameters determine whether the meter adds or subtracts the losses from the measured power. Compensation can be enabled using either the Vista component of ION Enterprise™ or ION Setup.

> **NOTE**: If the ION8650 or ION8600 meter is in Test Mode, making any configuration change will result in the meter exiting Test Mode.

Configuring loss compensation using Vista

1. Launch Vista.

2. In the User Diagram screen that appears, click the **Revenue** button.

3. Click the **Loss Compensation** button. The following window appears: (the screen for ION8600 Loss Compensation is shown in the following image)

A	Click here to enable loss compensation calculations
B	Choose either the Test Sheet or %Loss Constants compensation method
C	These are the true instrument transformer ratios. Normally they coincide with the Power Meter module's setup.

4. Configure your values as required.

    For a detailed explanation of values and their calculations, see "Loss compensation input parameters" on page 10.

Configuring loss compensation using ION Setup

1. Log on to ION Setup and connect to the appropriate meter.

2. Double-click the Setup Assistant and navigate to the **Revenue > Transformer Loss** screen.

3. Click the **Method Selection** tab to select how transformer loss information is entered.

4. Click either the **%Loss Constant** or the **Test Sheet** tab (depending on your selected

calculation method) and configure the value settings.
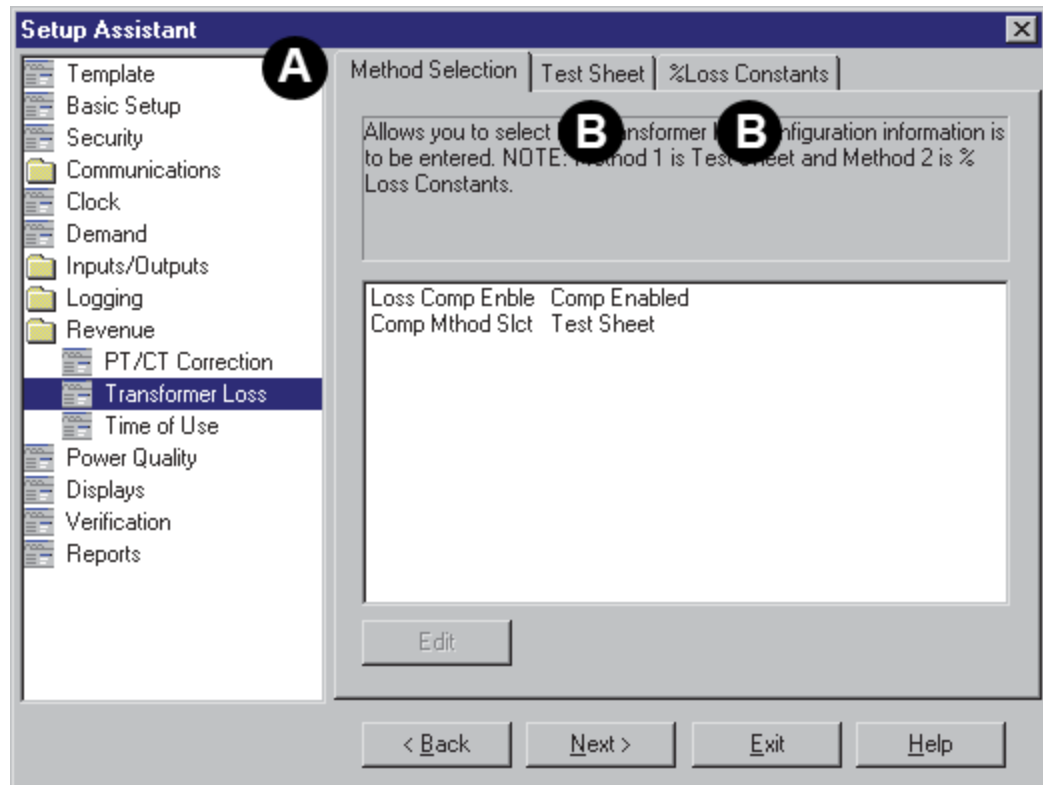
A	Enable your loss compensation in the **Method Selection** tab. Choose either the "Test Sheet" or %Loss Compensation" method.
B	Use the Test Sheet and %Loss Constants tabs to access and set the parameters of the loss compensation method you require.

Single-phase testing in ION Setup

You can also test transformer line loss with a single-phase source. To test with single-phase in ION Setup:

1. Log on to ION Setup and connect to the appropriate meter.

2. Double-click the Setup Assistant and select the **Verification** screen.

3. Select **Test Mode** and click **Display**. A window appears informing you the meter is now in Test Mode.

4. Select **Volts, Amps and Power**.

5. Click **Loss Mode** and select **Single Phase**.

6. In the Setup Assistant screen, navigate to **Revenue > Transformer Loss** and set your loss parameters.

Loss compensation input parameters

Depending on the method chosen for transformer loss compensation, the meter requires specific data parameters to be programmed into the meter. The data for each method is listed below. All parameters can be programmed into the meter using ION Enterprise or ION Setup software. The following is a detailed description of the input parameters required by both methods.

Input parameters for Method 1 (Test Sheet Method)

Line losses and transformer losses are calculated separately and applied to the measured power, energy and demand quantities based on the location of the meter with regards to the power transformer, supply-side line and load-side line.

All parameters required for this method can be obtained from the transformer and line manufacturer.

NOTE: The same unit of length (meter or foot) must be used for all parameters.

Line loss calculation parameters:

$$\text{Power Transformer Ratio} = \left(\frac{\text{Voltage on supply side}}{\text{Voltage on load side}} \right)$$

NOTE: The value of Power Transformer Ratio will be less than 1 for generation applications. If there is no power transformer used, set this value to 1.

For the line on the supply side (SY) of the transformer:

$$\text{Resistance/Unit length} \left(\frac{r}{l_{sy}} \right) \text{ in } [\Omega/m] \text{ or } [\Omega/ft]$$

$$\text{Reactance/Unit length} \left(\frac{x}{l_{sy}} \right) \text{ in } [\Omega/m] \text{ or } [\Omega/ft]$$

$$\text{Line length}_{sy} \text{ in } [m] \text{ or } [ft]$$

For the line on the load side (LD) of the transformer:

$$\text{Resistance/Unit length} \left(\frac{r}{l_{ld}}\right) \text{ in } [\Omega/m] \text{ or } [\Omega/ft]$$

$$\text{Reactance/Unit length} \left(\frac{x}{l_{ld}}\right) \text{ in } [\Omega/m] \text{ or } [\Omega/ft]$$

$$\text{Line length}_{ld} \text{ in } [m] \text{ or } [ft]$$

ION meters then calculate the line losses as:

$$\text{LLW[W]} = I^2_{avg} \times \frac{r}{l} \times \text{Line Length} \times 3 \qquad (13a)$$

$$\text{LLV[VAR]} = I^2_{avg} \times \frac{x}{l} \times \text{Line Length} \times 3 \qquad (13b)$$

These calculations are performed separately for the supply side part of the line and the load side part.

Transformer loss calculation parameters:

When this method is selected, then the following power transformer and line data is programmed into the meter:

- Rated power transformer voltage (V_{LL} on metered-side of power transformer)
- Rated power transformer kVA
- Power transformer ratio
- No-load iron test loss watts
- Full-load copper test loss watts
- Percent exciting current
- Percent impedance
- Line length of load-side and supply-side line
- Resistance and reactance per unit length for both lines
- Instrument transformer ratios (VTR, CTR)
- Information about the location of the meter with regards to the power transformer, supply-side line and load-side line

The iron and copper losses are then calculated using equations 7 to 12 ("Causes of line loss " on page 3), based on the measured load current and voltage.

Line loss and transformer loss compensation

After the losses are calculated, you can add or subtract losses from the measured active and reactive power values in real-time.

Metering location parameters:

- MP Definition 1 – Indicates if the power monitor (metering point) is installed on the supply side of the transformer or the load side.

- MP Definition 2 – Indicates if the power monitor (metering point) is installed on the transformer end of the line or on the far end.

Use cases: metering point and billing point locations

The following diagrams outline the possible locations of the billing points (BP) and metering points.
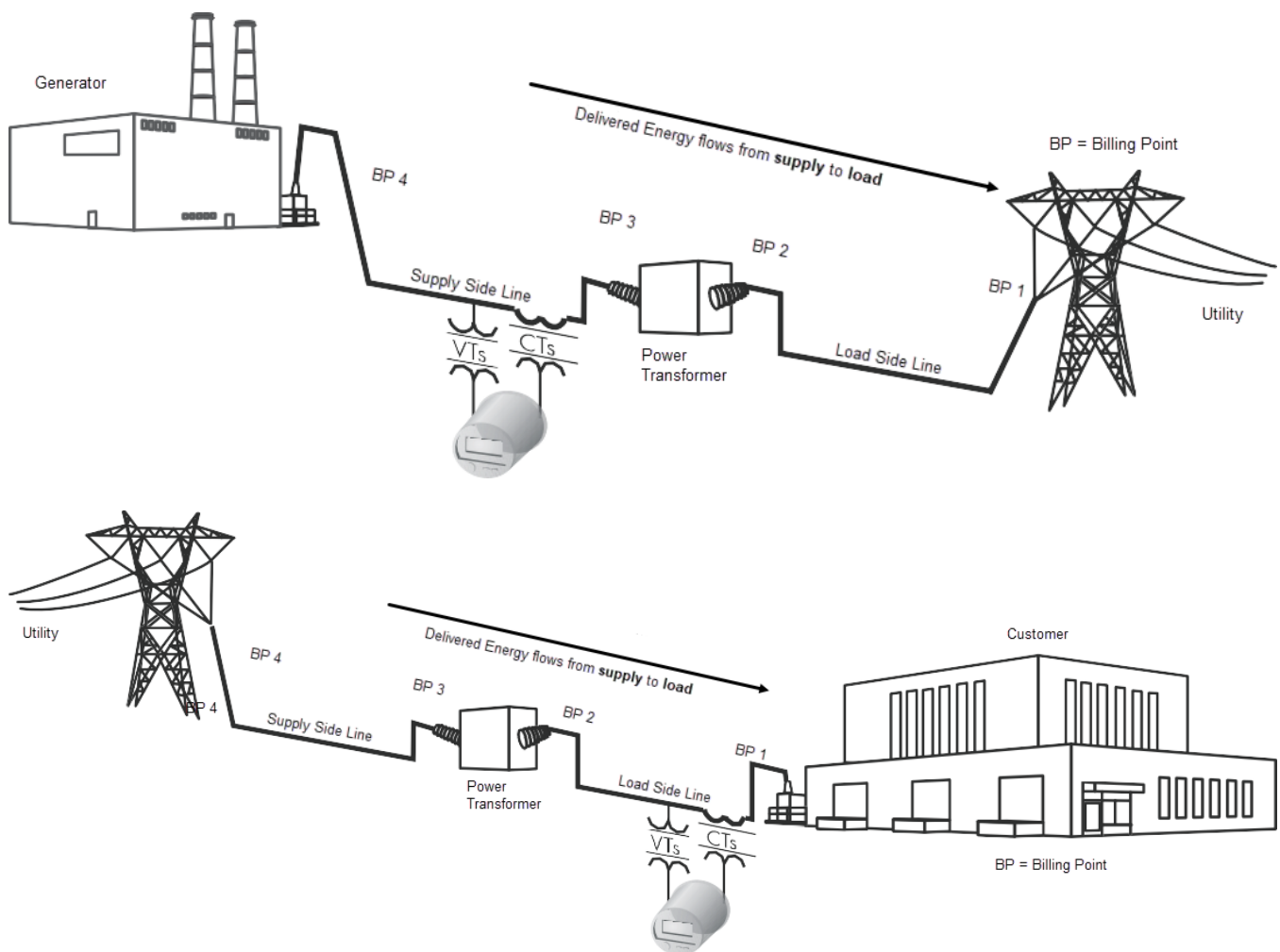
> **NOTE**: Some scenarios involve energy delivered from generator to the Utility, and others from the Utility to the customer.

The following examples show how the location of the power monitor and the billing point affect the calculation of compensated power values.

Line loss only

Line Losses **added** to power and energy quantities
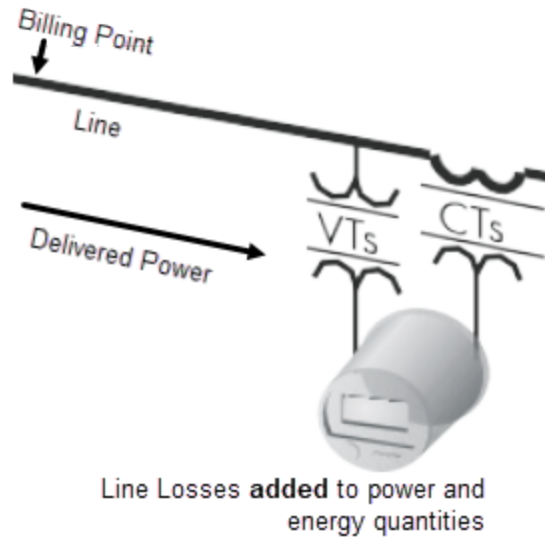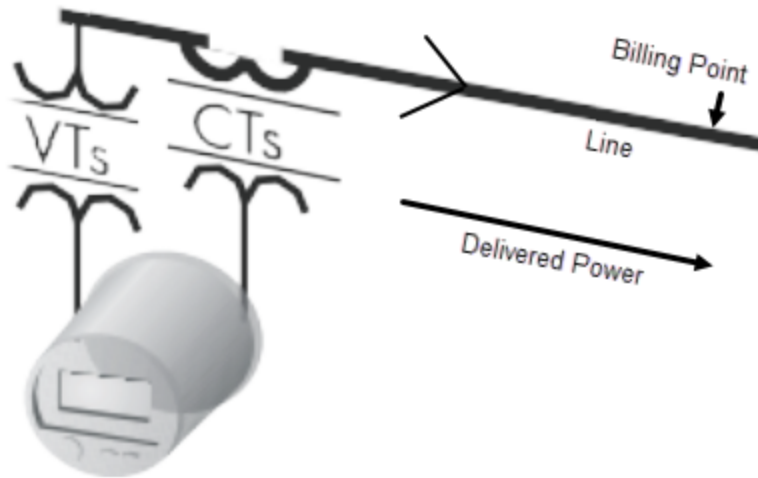
Adding line losses

Line losses are added to the delivered power and energy quantities. Set the loss calculation parameters in the meter as follows:

Parameter	Setting
MP Definition 1	select Load Side
MP Definition 2	select Not Transformer Side
PT ratio	enter instrument transformer data
CT ratio	enter instrument transformer data
r/l_{ld}	enter resistance in [Ω/m] or [Ω/ft]
x/l_{ld}	enter reactance in [Ω/m] or [Ω/ft]
Line length$_{ld}$	enter line length in [m] or [ft]

> **NOTE**: Leave all other parameters at their default settings ().
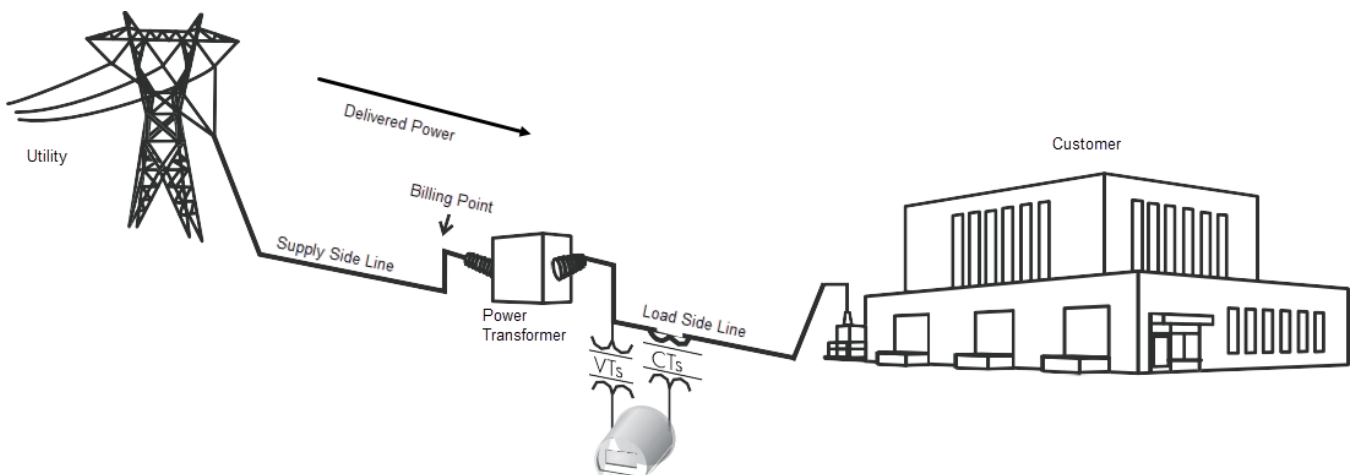
Subtracting line losses

Change MP Definition 2 to "Transformer Side" so that the line losses are subtracted from the power and energy quantities.

Line losses **subtracted from** power and energy quantities

NOTE: If you have a different line scenario, contact Schneider Electric's Technical Support.
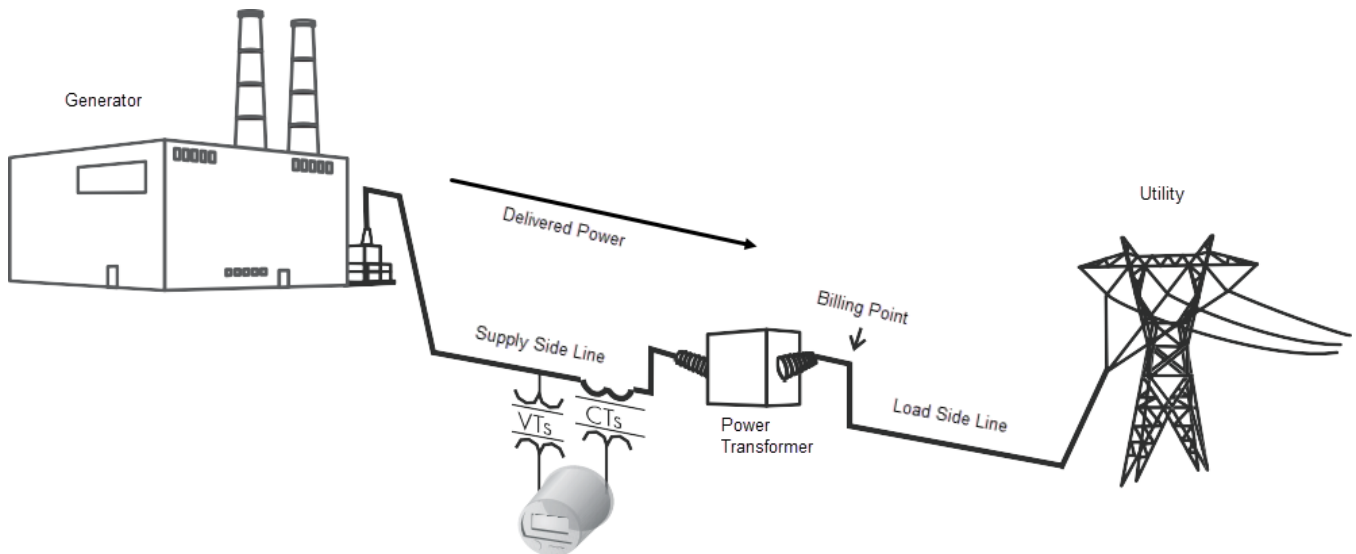
Transformer loss only

Adding transformer losses

Transformer losses are added to power and energy quantities. The loss calculation parameters in the meter should be set as follows:

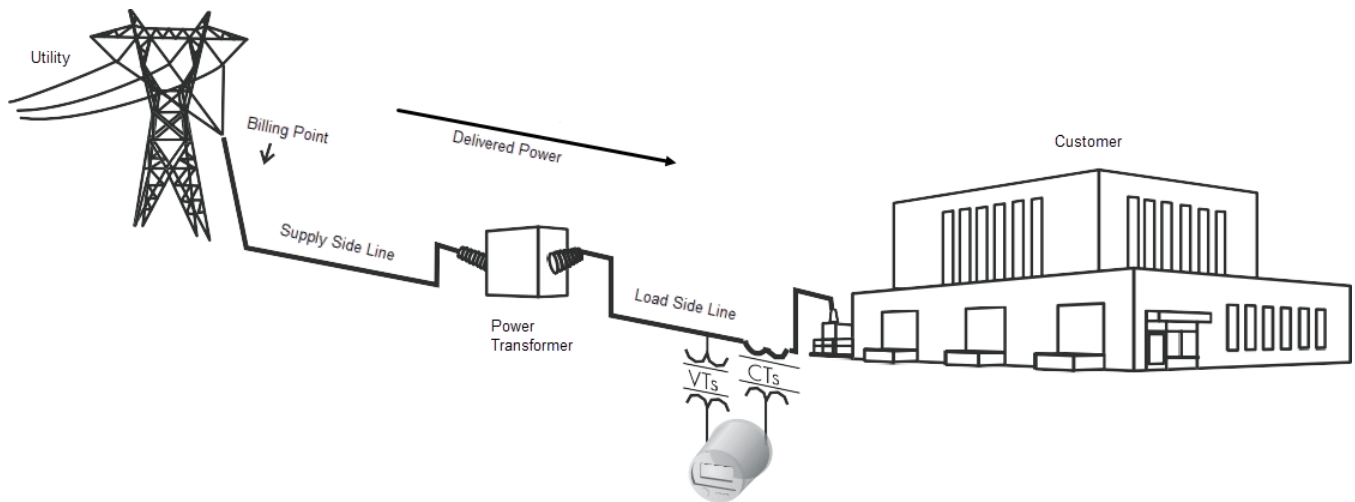| Parameter	Setting
MP Definition 1	select Load Side
MP Definition 2	select Not Transformer Side
PT ratio	enter instrument transformer data
CT ratio	enter instrument transformer data
VII$_{rated}$	enter Transformer data
LWFe$_{test}$	enter Transformer data
LWCu$_{test}$	enter Transformer data
%Excitation	enter Transformer data
%Impedance	enter Transformer data

NOTE: Leave all other parameters at their default settings (see diagram in the section, "Configuring loss compensation using Vista").

Subtracting transformer losses

Change MP Definition 1 to "Supply Side" so that transformer losses are subtracted from the power and energy quantities.

Line loss and transformer loss

Adding line an transformer losses

The transformer and line losses are added to measured power and energy values. Set the meter's loss calculation parameters to:

Parameter	Setting
MP Definition 1	select Load Side
MP Definition 2	select Not Transformer Side
PT ratio	enter instrument transformer data
CT ratio	enter instrument transformer data
Power Transformer Ratio	(Voltage on Supply Side/Voltage on Load Side)
VII_{rated}	enter Transformer data
$LWFe_{test}$	enter Transformer data
$LWCu_{test}$	enter Transformer data
%Excitation	enter Transformer data
%Impedance	enter Transformer data
r/l_{ld}	enter resistance in [Ω/m] or [Ω/ft]
x/l_{ld}	enter reactance in [Ω/m] or [Ω/ft]
Line lengthld	enter line length in [m] or [ft]

NOTE: Leave all other parameters at their default settings (see diagram in the section, "Configuring loss compensation using Vista"). To ignore load-side or supply-side line losses, set the corresponding length to zero (0).

Subtracting line and transformer losses

Change the MP Definition 1 to "Supply Side" so that losses are subtracted from power and energy quantities.
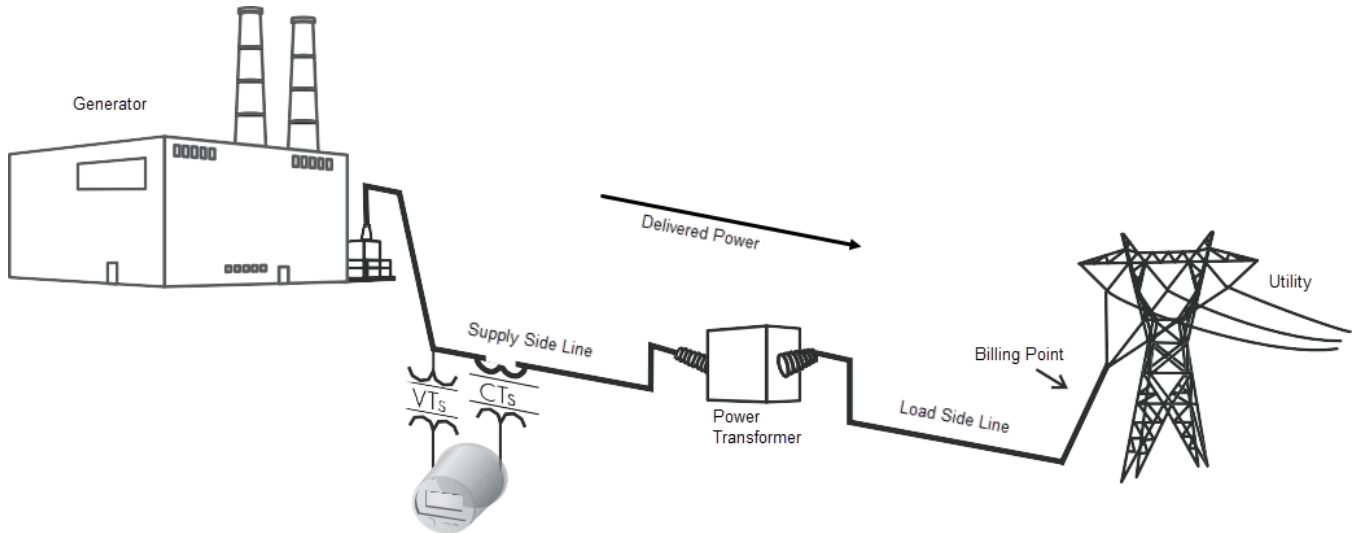
Input parameters for Method 2 (%Loss Constants)

NOTE: When using this method in ION meters with a delta connection, compute the %Loss values with respect to the single-phase system kVA. To confirm TLC operation, verify that the amount of compensated watts matches the expected. See formulas in "Percent-loss constant calculations " on page 18.

In this method, line loss and transformer loss calculation parameters are computed manually or through a third party program into four (4) loss constants. These values are then programmed into the meter. The meter uses these constants to calculate the losses and perform the compensation.

This method allows you to enable or disable iron and copper loss calculations separately. When this method is selected, the following data must be programmed into the meter:

- Percent iron watt loss constant (%LWFe)*
- Percent copper watt loss constant (%LWCu)*
- Percent iron VAR loss constant (%LVFe)*
- Percent copper VAR loss constant (%LVCu)*
- Instrument transformer ratios (VTR, CTR)
- Rated meter voltage (V_{Mrated})
- ½ Class meter current (½I_{Mrated})
- Number of stator elements (2 for Delta connections, 3 for WYE)

* If you want the losses to be subtracted from Delivered Energy, enter negative values for the percent loss constants.

The field **# Stator Elements** (see diagram in the section, "Configuring loss compensation using Vista " on page 7) indicates the number of metering elements to configure for transformer loss compensation:

ION8650, ION8600 Volts Mode	ION8800, ION7550, ION7650 Volts Mode	# Stator Elements
35S	Delta	2
9S, 36S, 29S	4-Wire WYE	3
	3-Wire WYE	

NOTE: These are the values you program into the ION meter. To properly implement transformer loss calculations using Method 2, you must calculate constants using the following relationships. See "Appendix A: Glossary" on page 20 and make sure you fully understand the terms used below. Failure to calculate exactly as outlined below will result in incorrect readings.

Percent-loss constant calculations

Both L-L, or both L-N

$$\%LWFe = \frac{LWFe_{TXtest} \times \left[\frac{V_{Mrated} \times VTR}{V_{TXtest}}\right]^2}{\frac{1}{2} \text{ Class System VA}} \times 100\% \qquad (14)$$

Both L-L, or both L-N

$$\%LVFe = \frac{LVFe_{TXtest} \times \left[\frac{V_{Mrated} \times VTR}{V_{TXtest}}\right]^4}{\frac{1}{2} \text{ Class System VA}} \times 100\% \qquad (15)$$

$$\%LWCu = \frac{LWCu_{TXtest} \times \left[\frac{\frac{1}{2}I_{Mclass} \times CTR}{I_{TXtest}}\right]^2 + LLW_{Mclass} \times CTR^2}{\frac{1}{2} \text{ Class System VA}} \times 100\% \qquad (16a)$$

$$= \frac{(\frac{1}{2}I_{Mclass} \times CTR)^2 \times \text{Total System Resistance}}{\frac{1}{2} \text{ Class System VA}} \times 100\% \qquad (16b)$$

NOTE: System Resistance and System Reactance include both transformer and line impedance.

$$\%LVCu = \frac{LVCu_{TXtest} \times \left[\frac{\frac{1}{2}I_{Mclass} \times CTR}{I_{TXtest}}\right]^2 + LLV_{Mclass} \times CTR^2}{\frac{1}{2} \text{ Class System VA}} \times 100\% \qquad (17a)$$

$$= \frac{\left(\frac{1}{2}I_{Mclass} \times CTR\right)^2 \times \text{Total System Reactance}}{\frac{1}{2} \text{ Class System VA}} \times 100\% \qquad (17b)$$

Where:

$$\frac{1}{2}\text{Class System VA} = V_{Mrated} \times \frac{1}{2}I_{Mclass} \times (\text{\# Meter Stator Elements}) \times VTR \times CTR \qquad (18)$$

Loss calculations in ION meters

ION meters use these constants to calculate the losses as follows:

$$LWFe = \frac{\%LWFe}{100} \times \frac{1}{2} \text{ Class System VA} \times \left[\frac{V_{actual}}{V_{Mrated}}\right]^2 \qquad (19)$$

$$LVFe = \frac{\%LVFe}{100} \times \frac{1}{2} \text{ Class System VA} \times \left[\frac{V_{actual}}{V_{Mrated}}\right]^4 \qquad (20)$$

$$LWCu = \frac{\%LWCu}{100} \times \frac{1}{2} \text{ Class System VA} \times \left[\frac{I_{actual}}{\frac{1}{2}I_{Mclass}}\right]^2 \qquad (21)$$

$$LVCu = \frac{\%LVCu}{100} \times \frac{1}{2} \text{ Class System VA} \times \left[\frac{I_{actual}}{\frac{1}{2}I_{Mclass}}\right]^2 \qquad (22)$$

Important note for percent-loss loss equations (14-17) and power loss equations (19 - 22)

Because the meter's first step in its loss calculations computation is to cancel out the "½ Class System VA" value, the "½ Class System VA" value that is used in the "Percent-loss constant calculations" on page 18 must be calculated exactly as outlined in equation 18. If the "½ Class System VA" value is not what the meter expects, the two terms will not fully cancel out. This will result in incorrect loss calculations.

Appendix A: Glossary

This glossary describes the electrical parameters used in both compensation methods.

Term	Definition
Vllrated (= V_{TXtest})	Rated line-to-line voltage of the power transformer on the metered side. This value must be entered in primary units as it is given in the transformer test sheet. Often the rated voltage and test voltage are the same.
I_{TXtest}	Rated current of the power transformer on the metered side (=average line current).
VA_{TXtest}	Rated kVA of the power transformer from the test sheet.
$LWFe_{TXtest}$	No-load test iron watt loss (= iron watt loss at rated power transformer voltage).
$LWCu_{TXtest}$	Full-load test copper watt loss (= copper watt loss at rated power transformer current).
$LVFe_{TXtest}$	No-load test iron VAR loss (= iron VAR loss at rated power transformer voltage).
$LVCu_{TXtest}$	Full-load test copper VAR loss (= copper VAR loss at rated power transformer current)
%Excitation	Power transformer no-load test current as a percentage of the rated transformer current.
%Impedance	Power transformer full-load test voltage as a percentage of the rated transformer voltage.
PT ratio (or VT ratio)	Voltage instrument transformer ratio. PT Prim / PT Sec
CT ratio	Current Instrument Transformer ratio. CT Prim / CT Sec
Line length SY	Power line length on the supply side of the power transformer.
Line length LD	Power line length on the load side of the power transformer.
r / l_{sy}	Supply side power line resistance per unit length.
r / l_{ld}	Load side power line resistance per unit length.
x / l_{sy}	Supply side power line reactance per unit length.
x / l_{ld}	Load side power line reactance per unit length.
MP Definition 1	Indicates if the power monitor is installed on the supply side of the transformer or the load side.
MP Definition 2	Indicates if the power monitor is installed on the transformer end of the line or on the far end.

Term	Definition
%LWFe	Percent of measured watts lost in the system due to the magnetizing inductance of power transformer.
%LWCu	Percent of measured watts lost in the system due to impedance in lines and windings.
%LVFe	Percent of measured VARs lost in the system due to the magnetizing inductance of power transformer.
%LVCu	Percent of measured VARs lost in the system due to impedance in lines and windings.
System resistance	Sum of power transformer and line resistance on all phases.
System reactance	Sum of power transformer and line reactance on all phases.
VMrated (rated meter voltage)	Nominal meter input voltage. This is the value used in the calculation of the Percent iron loss constants. The rated meter voltage will be a line-to-neutral voltage for 3-element metering and a line-to-line voltage for 2-element metering. The rated meter voltage must be entered in meter units (= unscaled).
$\frac{1}{2}I_{Mrated}$ (½ Class meter current)	Half the value of the certified meter class current. This value has to match the value used in the calculation of the Percent loss constants.
# of Stator Elements	Number of measuring elements used in the meter. This number is determined by the form factor of the power monitor. For example, 9S meters in a 4 wire application use 3 elements, while 35S meters used for 3 wire applications use 2 elements.
LLV_{Mclass}	Line loss VARs at the meter's ½ class current.
LLW_{Mclass}	Line Loss watts at the meter's ½ class current.

Appendix B: Loss compensation frameworks

Method 1 (Test Sheet)

The following screen capture shows the view of this framework in the Designer component of ION Enterprise:
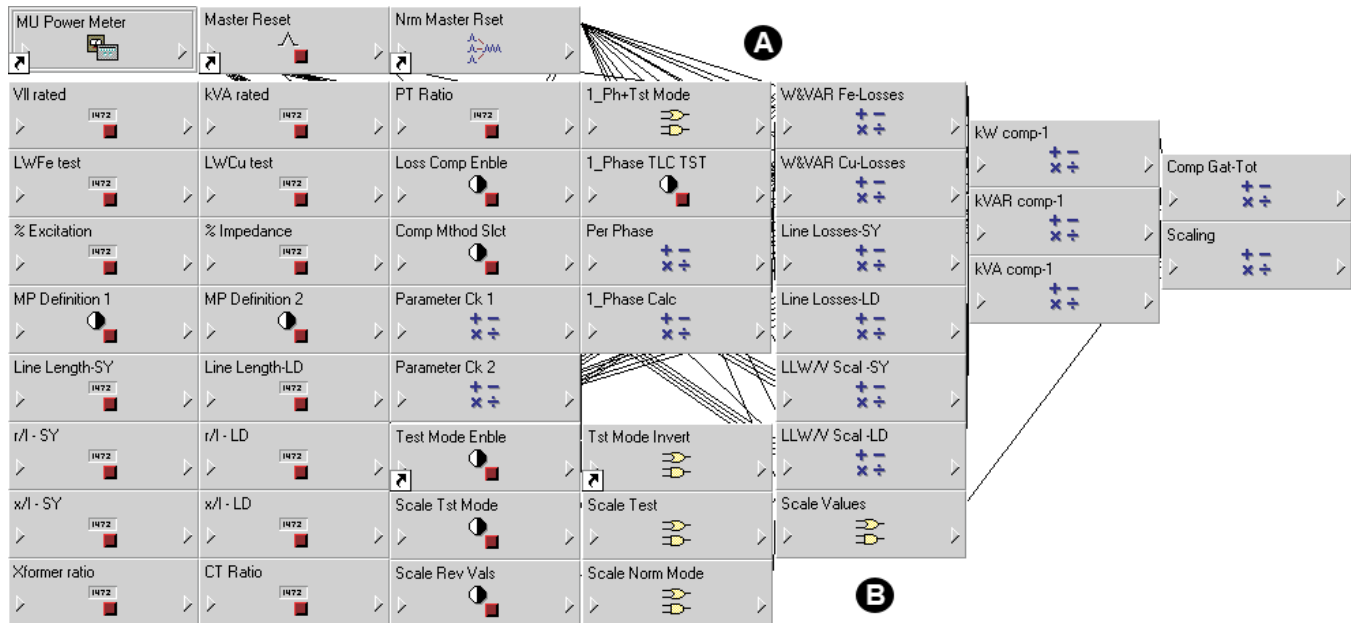
| A | Single-phase test option lets you use a single-phase source and view three-phase. |
| B | These modules let you select scaling in test and/or normal modes. |

On the left side are the External Numeric and External Boolean modules that are used to enter transformer and line data for the loss calculations. The Arithmetic modules perform the actual calculations.

Before the transformer and line data is passed into the Arithmetic modules that perform the loss calculations, the data is checked for invalid entries such as negative numbers to ensure that the outputs of the Arithmetic loss modules will always be available.

NOTE: A division by "0" or a negative number in a square root would cause a "Not available" output on the Arithmetic modules.

Line loss totals must be scaled prior to final energy scaling since the line losses are I2R (measured in watts). Note that there is no voltage component in this watts measurement. Scaling line loss prior to final power scaling provides CT2 as a multiplier for line losses:

$$\text{Line Loss} = [\text{Losses in MU}] \times [\text{PTR} \times \text{CTR}]$$

$$= \left[\frac{(I_{sec} \times \text{CTR})^2 \times R}{\text{PTR} \times \text{CTR}} \right] \times (\text{PTR} \times \text{CTR})$$

$$= \left[(I_{sec})^2 \times R \times \frac{\text{CTR}}{\text{PTR}} \right] \times (\text{PTR} \times \text{CTR})$$

Method 2 (%Loss Constants)

The following screen capture shows the view of the framework in Designer component of ION Enterprise:
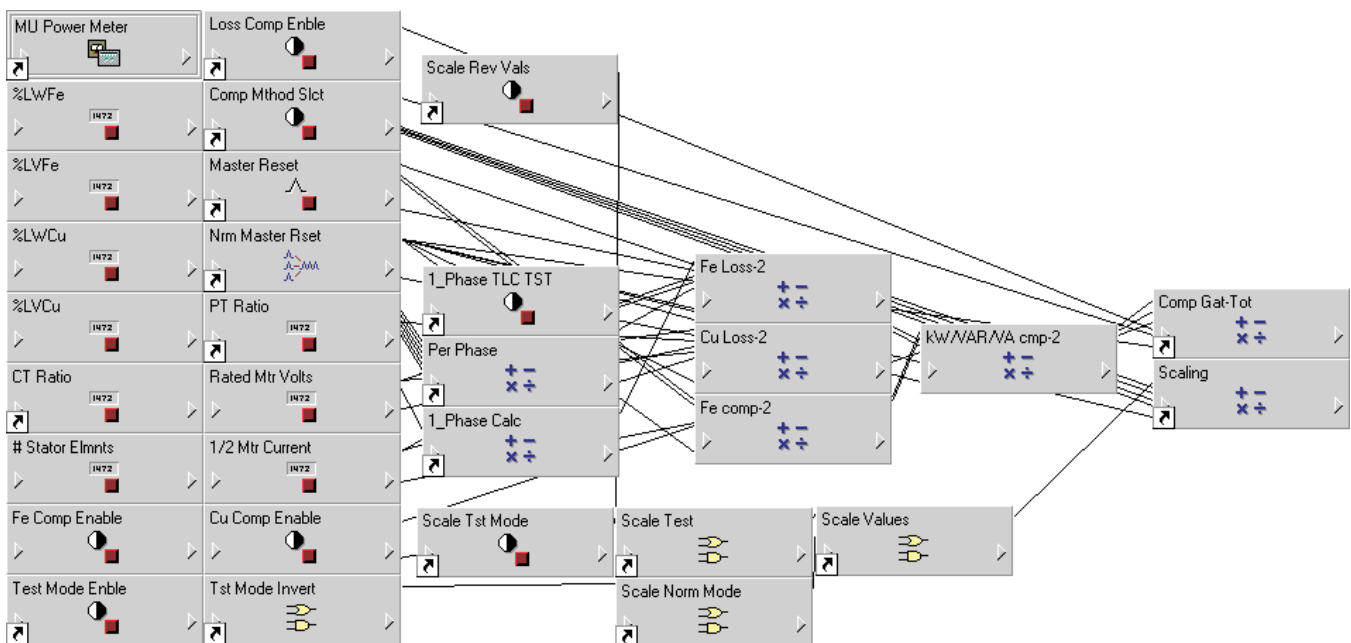
On the left side are the External Numeric and External Boolean modules that are used to enter transformer and line data for the loss calculations. The Arithmetic modules perform the actual calculations.

NOTE: The example Designer frameworks shown in Method 1 and Method 2 are provided here for illustration purposes only.

Single-phase testing

You can connect a single-phase source voltage in parallel and the current in series to simulate a three-phase source. Some ION meters automatically adjust the voltage in this test situation when the meter is in Test Mode and the single-phase option is selected.